ANATOMICAL AND HISTOLOGICAL STUDIES OF THE DIGESTIVE CANAL OF CIMBEX AMERICANA

by

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The digestive canal of various Hymenoptera has been described by many authors, viz., Swammerdam(27), Reaumur(22), Treviranus#, Brandt and Ratzeburg(7), Burmeister(8), Newport (20), Dufour(11), and more recently by Schliemenz(23) and Bordas(2,3,5&6). A few of these authors have extended their investigations to different species of the family Tenthredinidae. Burmeister has described the alimentary canal of Tenthredo nigra. Newport has worked on the anatomy of Athalia centifoliae. He described and figured the digestive canal of this species and did some work on the histological structure. Dufour(11) described and figured the anatomical relations of the digestive organ of a number of species of Tenthredinidae. More recently Bordas(2,3,5&6) investigated a number of species belonging to this family. His researches on the histological structure of the digestive canal were extended to several genera belonging to various families of Hymenoptera often not closely related.

The material for the present research was obtained in and near the city of Milwaukee, Milwaukee County, Wisconsin. The insects were all collected towards the end of June and the early part of July, usually upon the peach-leafed willow

#Paper not accessible.

(Salix amygdaloides, Anders.) and the long-leaved willow (Salix longifolia, Muhl). The males were usually found basking in the hot sunshine upon the leaves of these willows. The females were often taken while working their saws under the epidermis of the lower surface of the leaves, where they deposited their eggs on one or both sides of the mid-rib. Sometimes, however, the females were found girdling the branches with their strong mandibles.

METHODS

For general dissection the specimens were prepared by injecting 95% alcohol into them with a hypodermic syringe. For histological purposes the dorsal integument was removed and they were then thrown into the preserving fluid. Several methods of fixation were used, viz., Fleming's weak and strong solutions, Perenyi's fluid and a saturated aqueous solution of corrosive sublimate. In the last named method the insects were either killed in hot water to which, after a few seconds, an equal amount of a saturated aqueous solution of sublimate was added, or the insects, after being killed in hot water, were thrown directly into a hot saturated solution of sublimate. Here the insects were allowed to remain from twenty to forty minutes. They were then thoroughly washed in running water, and finally preserved by placing them in 50, 70, and 95% alchol consecutively. After this the different parts of the internal organs were dissected out and carried

through absolute alchol and xylol, infiltrated with 52° paraffine and finally sectioned, 4-12u. thick. The ordinary stains. Fleming's safranin, gentian violet and orange G; and haematoxylin followed by eosin gave most excellent results.

ANATOMICAL STRUCTURE OF THE DIGESTIVE CANAL.

The pharynx (Fig.3.ph), which lies wholly within the head, is dorso-ventrally flattened, it being a little broader and more compressed at the anterior than at the posterior end. Dorsally the pharynx has a thick layer of circular muscles; ventrally there is a brown chitinous plate, which ends posteriorly in two prolongations (Fig.1.pl). The pharynx, in passing through the head, runs in a posterior and slightly dorsal direction, until a position ventral to the brain is reached; here it passes over into the oesophagus, which, instead of continuing in the same direction as the pharynx, makes an angle with it and continues parallel to the long axis of the body.

At its beginning the oesophagus is as wide as the pharynx, but it gradually narrows and passes as a thin tube straight through the head and thorax. At the anterior end of the abdomen the oesophagus dilates to form the crop, which, when distended, extends back as far as the sixth abdominal segment (Fig.2.c). When, however, the crop is not distended, its wall is folded irregularly and from an external view, is hardly distinguishable from the oesophagus.

The gizzard is in the form of a short cylindrical tube; anteriorly it is pushed into the crop while posteriorly it is telescoped far into the mid-intestine. From an external view the only portion visible is a small, shightly-curved intermediate piece (Fig.2.g).

The mid-intestine is a straight tube which is widest at the middle third of its length. This region of the alimentary canal presents a series of circular folds, which are perpendicular to its long axis (Fig.2.md). A microscopical examination of the outer wall shows that there are a number of parallel longitudinal muscles, which send branches into the folds. At the anterior end of the mid-intestine these muscles leave it and attach to the gizzard; at its posterior end they pass backward between the Malpighian tubules and some continue as the external longitudinal muscles of the ileum.

The Malpighian tubules, ninety to one hundred in number, enter the mid-intestine near its posterior end. A little distance back of their entrance is a constriction, which marks the boundary of the mid-intestine and hind-intestine. Bordas(3) claims that, "Chez les Tenthredinidae(Emphytus) les tubes de Malpighi, en nombre tres restreint, de 20 a 25, sont inseres sur une seule rangee circulaire, un peu arriere de la portion retrecie du tube digestif, situee entre l'intestine terminal." According to Bordas, therefore, the Malpighian tubules of Emphytus, a Tenthredinida, must enter the hind-intestine, because they are inserted posterior to

the constriction. We find in Cimbex americana, also a Tenthredinida, that the Malpighian tubules enter the mid-intestine at a region anterior to the constriction(Fig.13.mlp).

The next division of the alimentary canal, the hind-intestine, is clearly separable into an anterior convoluted portion, the ileum(Fig.2.il), and a smooth, thicker posterior part, the rectum(Fig.2.r). The ileum is bent once or twice upon itself; the rectum passes as a straight tube through the rest of the abdomen. On the wall of the rectum and lying parallel with it, are six white elliptical thickenings, the rectal glands(Fig.2.rg). Three of these are situated a little anterior to the other three, which alternate with them.

HISTOLIGICAL STRUCTURE OF THE ALIMENTARY CANAL.

FORE-INTESTINE.

OESOPHAGUS:— A study of a series of cross sections through the oesophagus shows that at the beginning of this part of the fore-intestine, there is a large dorsal and a few smaller lateral and ventral folds(Fig.4). Passing backward this large dorsal fold decreases gradually in size, but as it becomes smaller, the lateral and ventral ones become more numerous. In the posterior head region the dorsal fold cannot be distinguished, but here the folds are very irregular in shape and almost fill the lumen. Internally the lumen is bounded by a hyaline chitinous intima, which is thickest immediately posterior to the pharynx. Throughout the rest of

the oesophagus it varies but little in thickness. The chitinous intima rests upon an epithelial layer which, at the anterior end of the oesophagus, is represented by cells with cell boundaries usually indescernable. Here and there between these epithelial cells are multinucleated glands, which are usually found within the folds(Fig.4.gla). The nuclei of these glands are larger than those of the epithelium. Usually one or more canals can be traced from these glands passing through the chitinous intima and opening into the lumen of the oesophagus(Fig.4.pc). In the posterior head region and throughout the rest of the oesophagus we find an epithelial layer, which is represented chiefly by ovoid nuclei, between which no cell boundaries are discernable. The multinucleated glands and their canals have here entirely disappeared. External to this epithelial layer lie the longitudinal muscles, and outside of these, the circular. The circular muscles at the anterior end of the oesophagus are from three to four layers in thickness, but in the thoracic region, they are rarely more than two layers. In the thoracic region the circular muscles do not always encircle the oesophagus at right angles to its long axis, but often run obliquely. The circular muscles are covered externally by a peritoneal membrane.

Bordas(3) has extended his researches to several genera of Hymenoptera; he finds that families which are not closely related:-- Bombinae, Sphecinae, Vespinae, Polistinae,

etc., show a great similarity in the structure of the alimentary canal. His results for all these being nearly the same, he takes as a type of his description Vespa crabo. For this species he describes(p.272) the muscular layers of the oesophagus and crop as follows:-- "Ils comprennent, en allant de l'interieur vers l'exterieur, une couche chitinense, incolore, generalement peu epaisse et reposant sur une tres mince couche cellulaire; vient ensuite une enveloppe musculaire formee par des fibres circulaires, abondantes surtout a la base des sinuosites rentrantes; eufin, exterieurement existe une assise constituee par des faisceaux musculaires longitudinaux." In a later work(5)(p.361), he again describes the muscular layers of Vespa crabo as follows:-- "Man findet demnach auf einem zur Achse senkrechten Schnitte, von aussen nach innen gehend, die folgenden verschiedenen Schichten:

1. Eine sehr feine peritoneale Membran, die sich über den Oesophagus, Kropf and ganzen Darm ausdehnt(mp).

2. Eine erste Lage von Ringmuskelfibrillen, die durch die fast regelmässige Überlagerung von zwei oder drei Schichten, welche überall dieselbe Dicke besitzen, gebildet wird(fc).

3. Längsmuskeln(fl). Diese letzeren sind in Bundeln von verschiedener Zahl angeordnet. Die auf dem Querschnitt dreiseitigen in den Oesophagealraum vorragenden Bündel bilden so eine Art inner Falten. Zwischen diesen letzeren nehmen andere Längsmuskelbündel die Räume verminderten Umfanges in bezug auf die vorigen gruppen ein. Die Zahl der Longitudinal

schichten ist sehr verschieden. Das, was diese Muskulatur charakterisiert, ist ihre Anordnung, die Unregelmassigkeit ihrer Dicke and vor allem ihre Falten." In the first mentioned paper(3) Bordas claims that external and inner circular muscles are present, the latter being especially abundant at the base of the sinuous folds; in the second paper(5), however, he does not mention these external longitudinal muscles, but claims that internal longitudinal muscles are present. He figures, in his later work(5), a cross section of the oesophagus and shows the circular muscles far removed from the folds. but at those regions where the inner longitudinal muscles are arranged in groups they are present even at the base of the folds.

CROP:-- The histological structure of the walls of the crop tends to prove that it is simply a dilation of the posterior end of the oesophagus. The internal folds of the walls are somewhat larger and more numerous in the crop than in the oesophagus(Fig.7.fc). We find no distinction in the epithelium between the oesophagus and crop; the cells of both parts being represented chiefly by ovoid nuclei, between which no cell boundaries are discernable. Towards the posterior region of the crop some of the internal longitudinal muscles penetrate the circular layers and continue as external longitudinal muscles, which attach to the chitinous intima at various parts of the gizzard(Fig.7.lmc).

GIZZARD:— A longitudinal section through the proventriculus shows that it may be divided into three parts:— 1, an anterior portion invaginated into the crop ("Verschlusskopf" of Schiemenz(23)); 2, a central part, easily seen in a dissection(Fig.2.g)("Fals" of Schiemenz(23) and "pedunculus" of Bordas(5)); and 3, a posterior portion telescoped far into the mid-intestine ("Zapfen" of Schiemenz(23) and "appendix vermiforme" of Bordas(5)).

The histological change, at the place where the crop passes over into the gizzard, is abrupt. At this region the large narrow folds of the crop gradually become flattened and finally form an almost unfolded chitinized epithelium, which continues over into the unfolded chitinized epithelium of the gizzard. In the former the thin hyaline chitinous layer with its numerous blunt projections passes over, in the gizzard, into a thick intima which has numerous long, backwardly-pointing bristles(Fig.7.b). The cellular change between these two parts of the fore-intestine is more abrupt. The ovoid nuclei of the epithelial cells of the crop assume a direction parallel to the almost unfolded chitin; these cells are then replaced in the gizzard by cubical cells with large spherical nuclei.

The most striking feature in a longitudinal section of the gizzard is the thickness of the muscles layers and their attachments. Externally, some of the longitudinal muscles can be traced from the mid-intestine directly to the

gizzard; others, however, like some of the longitudinal muscles of the crop, attach to the chitinous intima of the gizzard(Fig.7.lm1.mid). Numerous branches from these external longitudinal muscles, and sometimes an entire fibre penetrate the circular and inner longitudinal layers(where the latter are present), spread out somewhat fan-shaped just before reaching the epithelial cells, and finally attach to the chitinous intima. This peculiar branching continues from the beginning of the mid-intestine as far as the external longitudinal muscles extend anteriorly(Fig.7.blm). Some of the external longitudinal muscles attach to the chitinous intima near the beginning of the gizzard. The circular muscles just internal to these longitudinal ones are exceedingly thick; they attain their maximum thickness near the beginning of the "pedunculus" and disappear near the anterior end of the appendix. Following these circular layers within are the inner longitudinal muscles, which attach anteriorly to the chitin of the gizzard(Fig.7.ilm); posteriorly, some of these muscles attach to the chitinous layer at the anterior end of the "pedunculus", while others can be traced to the posterior end of it.

A transverse section through the anterior part of the gizzard shows that the strongly chitinized walls are thrown into four large folds or valves(Fig.5). From the thick chitinous intima numerous long yellowish bristles project into the lumen(Fig.5.b); these undoubtedly as in the honey-bee, serve as a sort of filter. Next outside of the

chitinous intima is an epithelium, which is made up of cubical cells containing a large spherical nucleus. Within the four irregular folds or valves is the next layer, the internal longitudinal muscles. Some of the branches from the external longitudinal muscles pass into these folds and attach to the chitinous intima; others attach to the chitin between the folds(Fig.5.blm). Surrounding the four valves are the greatly developed circular muscle layers, which serve to contract the four powerful folds. Outside of the circular muscles are the external longitudinal muscles, which are covered externally by a thin peritoneal membrane.

A study of a series of transverse sections through the gizzard shows that these four valves do not extend throughout its entire distance; secondary folds make their appearance, which, posteriorly, gradually become larger and larger, until they are equal in size to the primary ones. The bristles, which project from the chitinous intima into the lumen of the anterior part of the gizzard, have disappeared near the beginning of the "pedunculus". Fig. 6, a transverse section through the posterior end of the "pedunculus", shows that at this region the folds have become nearly equal in size but are not regular in shape. Within the folds, as well as between them, branches from the external longitudinal muscles are found to attach to the chitinous intima.

The appendix("Zapfen" of Schiemenz(23) or "appendice

vermiforme" of Bordas(5)),a continuation of the"pedunculus", is a cylindrical tube with irregular longitudinal folds, and is telescoped far into the lumen of the mid-intestine. A longitudinal section through it shows that the chitinous intima, which is a direct continuation of the somewhat thicker chitin of the "pedunculus", continues back as a very irregular layer with numerous, large, sharply-pointed projections to the posterior opening of the appendix(Fig.7.app). The chitin becomes gradually thinner as it bends upon itself and then extends anteriorly as an outer chitinous intima of almost uniform thickness. This outer intima is covered with numerous blunt projections, which do not disappear until near the place of union with the mid-intestine. Here it gradusIly becomes thinner and thinner, and finally is replaced by the cilia-like border of the mid-intestine(Fig.7.sm). In most of the longitudinal sections the outer chitinous intima was separated from the underlying cellular layer, a peculiarity which Bordas(5) has also noticed. In the tubular part of the appendix the epithelial cells are very much flattened with cell boundaries not discernable. Each cell contains a single ovoid nucleus which has its long axis parallel to the chitin. These epithelial cells continue as such around the posterior opening of the appendix, but gradually increase in size anteriorly and finally are replaced by the long cylindrical epithelial cells of the mid-intestine. Between the two epithelial layers of the appendix is a narrow space which is filled

with connective tissue(Fig.7.cct). At the anterior part of the appendix numerous branches from the external longitudinal muscles of the gizzard attach to the inner chitinous intima.

Bordas(5) determined experimentally the function of the appendix in Vespa. His results which are of special interest are as follows:-- "Das Zurücktreten der Nahrung von hinten nach vorne zu verbindern, d.h. vom Mitteldarm während dessen peristaltischen Bewegungen zum Kropfe, fällt im besonderen dem würmförmigen Appendix zu, der der Darmklappe bei den Apidae und anderen Insekten entspricht. Ich habe tatsächlich experimentell festgestellt, das der Rücktritt der Nahrung unmöglich ist. Es genügt hierfür eine gefärbte Flüssigkeit in den Mittledarm von Vespa zu injizieren. Übt man dann einen Druck von hinten nach vorne aus, bemerkt man, dass nicht ein Tropfen der Flüssigkeit in dem wurmförmigen Appendix gelangt und dass sie sich zwischen seinen äussern Wänden und denen des Mitteldarmes anhaüft. Über dies ist est leicht einzusehen, dass, je grösser der auf die Flüssigkeit ausgeübte Druck ist, diese umsomehr die Wände des Appendix zusammenpresst und seinen Verschluss um so hermetischer macht, der so das Eindringen jeder Substanz, sei sie flüssig oder nicht, durch die Endöffnung verhindert."

MID-INTESTINE.

Throughout the mid-intestine the transversely folded wall is nearly uniform in structure and consists of a

number of layers which are, passing from within, outward:-- 1, a layer of cylindrical epithelial cells with a cilia-like border bounding the lumen and groups of regenerating cells ("drüsen-crypten" of Frenzel(13), "drüsen" or "crypten" of Faussek(12), "germinal buds" of Miall and Denny(18) and "nidii" of Needham(19)) scattered among their bases; 2, a membrana propria, or basement membrane; 3, a layer of circular muscles; 4, a layer of longitudinal muscles; and 5, a peritoneal membrane.

A study of the free edge of the epithelial cells shows the presence of secretory processes, which are formed by strangulation. The secretory processes are of two kinds; the larger generally represents a large part of an epithelial cell and sometimes includes its nucleus, while the smaller is much more numerous and never contains a nucleus. These larger secretory processes are usually pyriform in shape and protrude far above the cilia-like border of the epithelial cells. In Fig.11, the large secretory process(lsp)has the appearance of having been crowded out by the compression of the adjacent cells. The smaller kind of secretory processes are stalked granular globules in direct continuation with the protoplasm of the cell from which they have originated(Fig.11. ssp). We could observe only one way in which the secretory processes became liberated into the lumen of the intestine; they were simply constricted off from the cell and were then free to circulate within the intestine(Fig.11.sp).

The epithelial layer consists of two markedly different parts; the elongated cylindrical epithelial cells, and little groups of regenerating cells lying at their bases. On account of the regular transverse folds of the mid-intestine the epithelial cells are of various forms and dimensions according to their position. They are usually elongated, and more or less rounded towards their free ends. Toward the basal end of the cells the cytoplasm shows in many places, a distinct longitudinal striation(Fig.10&11.ls), and more noticeable in some sections than in others; the cells, especially at the free ends are partially filled with globules, which stain a bluish color with Haematoxylin. These globules are not uniformily distributed throughout the cell; they usually decrease in number toward the basal end. Here and there, however, there are cells in which even the basal portions is crowded with globules. Each epithelial cell contains a single spherical or ovoid nucleus, which contains a small number(one to six) of nucleoli. Here and there young cells, each containing a small nucleus, are wedged in between older ones. Clustered together just inside of the basement membrane between some of the epithelial cells are small groups of from one to six or more regenerating cells(Fig.10. rc). We were unable to find any globules in the regenerating cells, but the cytoplasm stains lighter than the cells of the regular epithelium. The nuclei of these regenerating cells are smaller and stain deeper with Haematoxylin than do the

nuclei of the long cylindrical epithelial cells.

The basement membrane, upon which rests the epithelium, is covered with a layer of circular muscles; these are abundant especially at the inner end of the transverse folds. Outside of the circular muscles are the longitudinal, which, in an external view, appear as longitudinal fibres running parallel to one another. From these, branches are given off, which pass into the transverse folds of the mid-intestine. In a longitudinal section we were unable to ascertain with certainty the attachment of these branches. The longitudinal muscles extend posteriorly between the Malpighian tubules and some continue as the external longitudinal muscles of the ileum.

MALPIGHIAN TUBULES:-- A transverse section through the digestive canal at the entrance of the Malpighian tubules shows that each opens separately, and that they do not all enter the mid-intestine in the same plane. Anterior and posterior to their entrance, the epithelial cells of the mid-intestine become somewhat smaller, and gradually in the Malpighian tubule assume a more or less flattened shape. Each cell contains a single ovoid nucleus, which has its long axis parallel to the same axis of the tubule. The cilia-like border is continuous from the wall of the mid-intestine over in the Malpighian tubules whose entire inner surface it covers (Fig.13&14.sm).

A more minute study of the Malpighian tubules

shows that in a transverse section the cells are generally six in number and arranged in a circle. Each cell is somewhat longer than wide with its inner surface rounded. The cilia-like border which rests upon this rounded surface bounds a more or less sinuous lumen(Fig.9.sm). A peculiarity noticeable in the cells of some tubules, is the presence of bluish staining globules, which, in general appearance, resemble those in the epithelial cells of the mid-intestine (Fig.9.gl). The cells rest upon a basement membrane, external to which is a thin peritoneal membrane(Fig.9.np).

HIND-INTESTINE.

ILEUM:-- Posterior to the entrance of the Malpighian tubules, the mid-intestine continues back a short distance and then passes over into the hind-intestine. Histologically, we find an abrupt change; the long cylindrical epithelial cells of the mid-intestine are replaced at the beginning of the hind-intestine by smaller cells with relatively small nuclei. The cilia-like border, which covers the inner surface of the entire mid-intestine and Malpighian tubules is replaced in the ileum by a hyaline chitinous intima(Fig. 8).

PYLORIC VALVE:-- A longitudinal section through the anterior part of the ileum shows the presence of the so-called pyloric valve(Fig.13.pv)("valvule rectale" of Balbiana#,

Quoted from Van Gehuchten's paper.

"sphincter de l'intestine grele" of Van Gehuchten(15)). The lumen of the canal decreases abruptly in size immediately posterior to the boundary between the mid-intestine and hind-intestine. Numerous conical, backwardly-pointing spines project from the thin chitinous intima into the lumen of the pyloric valve. The circular muscles are greatly developed and according to Van Gehuchten, "peuvent etre consideres comme un appareil d'occlusion, destine a empecher les matieres alimentaires, soit de passer trop vite dans l'intestine terminal, soit de reveuir du gros intestine dans le ventricule chylifique."

A transverse section through the pyloric valve shows that the epithelial layer, which is lined with a chitinous intima, is thrown into a number of broad folds(15 to 18). The epithelial cells of these folds are little longer than broad, while in the space between the folds they are more flattened. The long axis of the ovoid nuclei is usually at right angles to the chitinous intima. External to the thick circular muscles are the longitudinal, which can be traced from the mid-intestine, between the Malpighian tubules over to the ileum. These are covered externally by the peritoneal membrane.

Posterior to the pyloric valve the folds of the ileum become less numerous and very irregular in shape. The conical spines which project from the chitinous intima into the lumen of the pyloric valve are replaced by blunt project-

ions. The cells contain a slightly granular cytoplasm, which, at places, shows a distinct longitudinal striation. The nucleus, usually ovoid in shape, takes up the larger part of the cell(Fig.12). The circular muscles, after their temporary thickening at the pyloric valve pass over into a thin layer. From the external longitudinal muscles branches are given off which enter the folds of the ileum and attach to the chitinous intima. The longitudinal muscles are covered by a thin delicate peritoneal membrane.

The ileum is invaginated into the rectum, as is shown in a longitudinal section through these two parts(Fig. 15.il). At this region, the ileum attains a somewhat better development of the circular muscles, and the folds almost fill up the entire lumen. Evidently this great development of the circular muscles serves, when they contract, to retain the nourishment within the ileum. According to Newport(20) the ileum of Athalia Centifoliae also ends in a valve. We propose to call this valve, the posterior iliac valve, to distinguish it from the pyloric valve("valvule rectale" of Balbiani, "sphincter de l'intestine grele" of Van Guchuten(15)) of the anterior ileum.

RECTUM:-- The rectum shows a marked histological difference from the ileum. Near the boundary between these two divisions of the hind-intestine, the cells of the ileum become smaller and pass abruptly into the much reduced cells of the rectum. The walls of the entire rectum, with the

exception of the rectal glands, is thrown up into irregular internal folds. The cells , with cell boundaries indiscernable, are represented chiefly by their nuclei. These cells and the folded nature of the rectum shows a marked similarity to the structure of the oesophagus and crop.

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EXPLANATION OF PLATE I.

All figures except general dissections drawn with a camera lucida. Magnifications in diameters given after the explanation of each figure.

Fig.1. Epipharynx and pharynx with dorsal wall not shown:-- vp., ventral plate of pharynx; lm., bundles of longitudinal muscles which are inserted at the base of each side of the epipharynx; pl., prolongations of posterior part of pharynx. X40.

Fig.2. Dissection showing dorsal view of alimentary canal:-- ph., pharynx; vm., vertical muscles; oes., oesophagus; c., crop; g., gizzard; md., mid-intestine; il., ileum; mlp., Malpighian tubules; r., rectum; rg., rectal glands. X4.

Fig.3. Cephalic integument of head removed showing the pharynx and brain:-- m., mandible; eph., epipharynx; ph., pharynx; br., brain; cp., compound eye; oc., three ocelli; fr., frontal ganglion; a., antennal lobe. X6.

Fig.4. Cross section of oesophagus near pharynx showing the large dorsal fold:-- ch., chitinous intima; ep., epithelium; ilm., longitudinal muscles; cm., circular muscles; gla., multinucleated gland; pc., pores which penetrate the chitinous intima. X216.

Fig. 1.

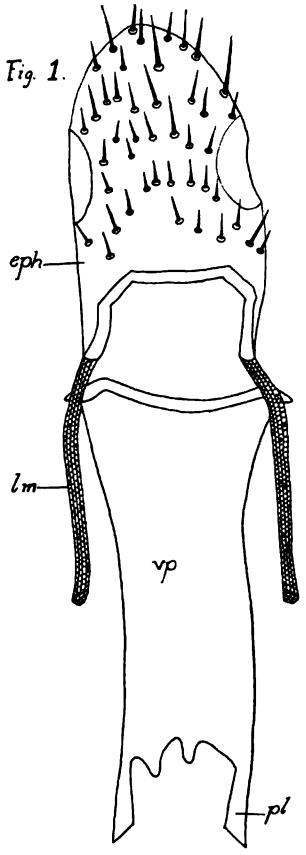
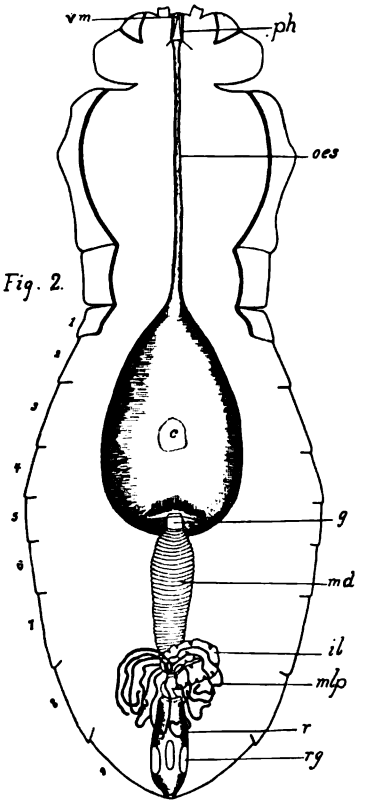


Fig. 2.



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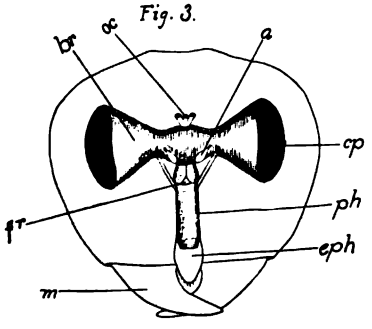

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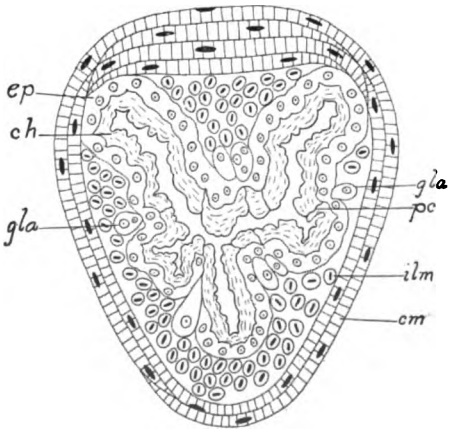


EXPLANATION OF PLATE II.

Fig.5. Transverse section through the anterior part of the gizzard showing four large folds:-- b., bristles; ch., chitinous intima; ep., epithelium; ilm., inner longitudinal muscles; cm., circular muscles; elm., external longitudinal muscles; blm., branch of the external muscles; the peritoneal membrane is not shown. X150.

Fig.6. Cross section through the posterior end of the pedunculus:-- Lettering as in Fig. 5. X150.

Fig.7. Longitudinal section through the gizzard; the anterior part is invaginated into the crop(c) and the posterior portion is telescoped into the mid-intestine(md): lmc., external longitudinal muscles which pass over from the crop and attach to the chitinous intima of the gizzard; fc., folds of the crop; b., bristles; ch., chitinous intima; nep., nucleus of epithelial cell; cm., circular muscles; ilm., inner longitudinal muscles; elm., external longitudinal muscles; blm., branches of external longitudinal muscles and occassionaly an entire muscle fibre penetrates the circular muscles and attaches to the chitinous intima; p., peritoneal membrane; lm.md., longitudinal muscles which pass over from the mid-intestine and attach to the chitinous intima of the gizzard; bo., boundary between gizzard and mid-intestine; sm., cilia-like border of epithelial cells of mid-intestine; app.,

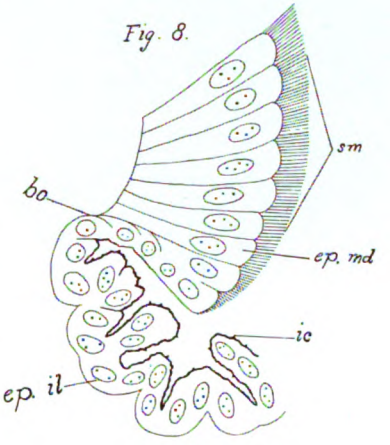
appendix; ect., connective tissue. X66.

Fig.8. Part of a longitudinal section showing cellular change between mid-intestine and hind-intestine:— bo., boundary between mid-intestine and ileum; sm., cilia-like border of epithelial cells of mid-intestine; ep.md., epithelial cells of mid-intestine; ep.il., epithelial cells of ileum; ic., chitinous teeth. X633.

Fig.9. Cross section of Malpighian tubule showing numerous globules(gl):— nep., nucleus of epithelial cell; sm., cilia-like border of epithelial cell; bm., basement membrane; np., nucleus of peritoneal membrane. X633.

Fig. 6.

Fig. 8.



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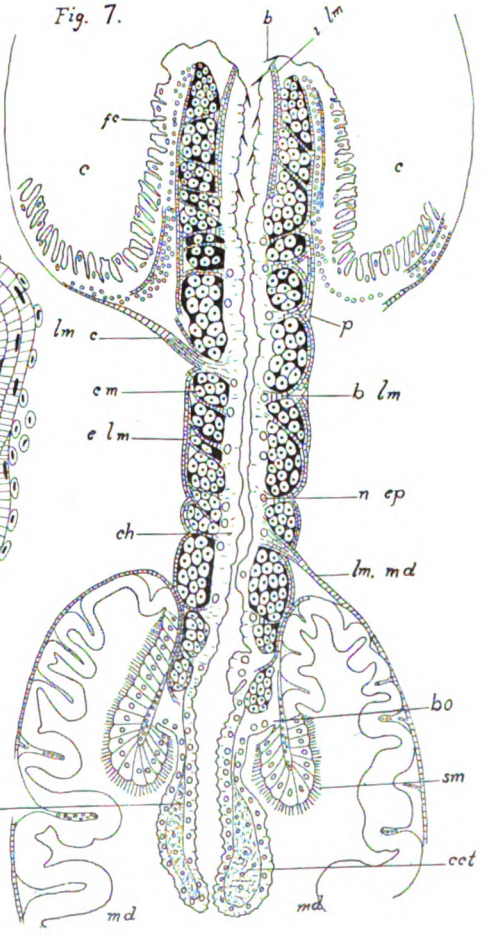

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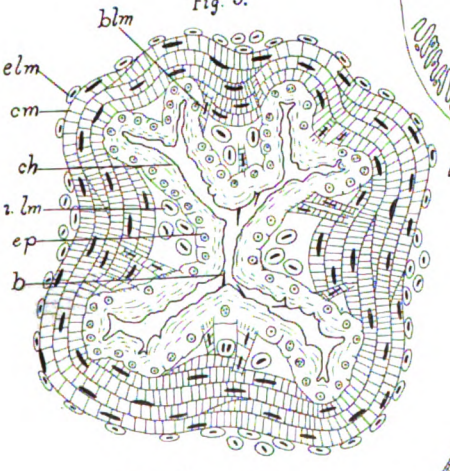
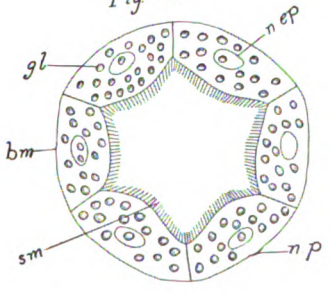


Fig 9.



EXPLANATION OF PLATE III.

Fig.10. Epithelial cells of mid-intestine with a regenerating center(rc):—sm., cilia-like border; nep., nucleus of epithelial cell; ls., longitudinal striations of cytoplasm; bm., basement membrane. X760.

Fig.11. Epithelial cells of mid-intestine with secretory processes:— lsp., large secretory process; ssp., small secretory process; sp., secretory process which has been constricted off from epithelial cell and is free to circulate in the mid-intestine; sm., cilia-like border of epithelial cells; ls., longitudinal striations of cytoplasm; bm., basement membrane. X640.

Fig.12. Cells of ileum:— nep., nucleus which takes up the greater part of the cell; ch., chitinous intima; the muscular layers are not shown. X760.

Fig.13. Longitudinal section through mid-intestine and hind-intestine showing pyloric valve(pv):— bo., boundary between mid-intestine and hind-intestine; ep., epithelium; sm., cilia-like border of epithelial cells of mid-intestine; mlp., Malpighian tubule opening into mid-intestine; elm., external longitudinal muscles; cm., circular muscles; blm., branch of external longitudinal muscles; ch., chitinous intima. X80.

IV.

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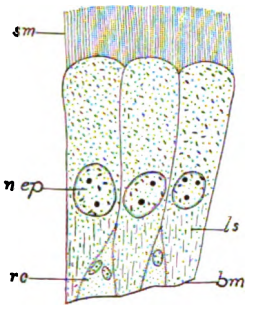
X116.

Fig. 10.



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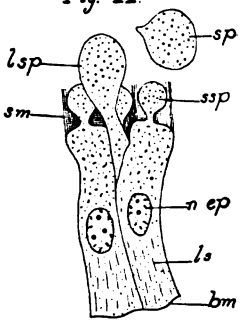

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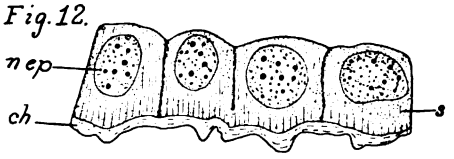

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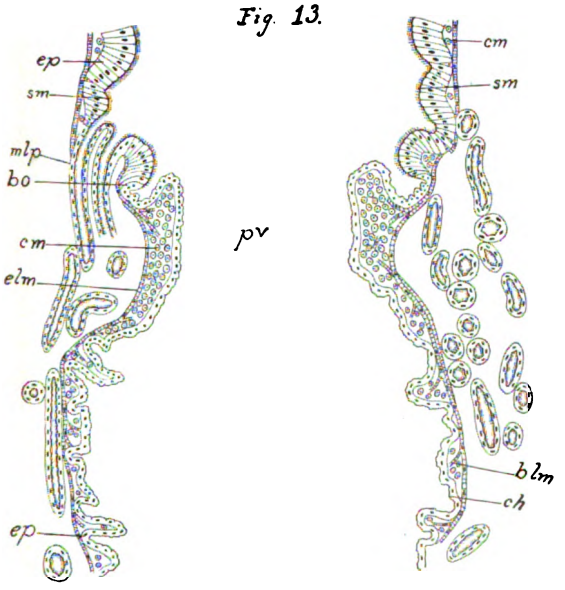

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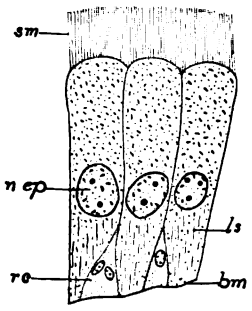

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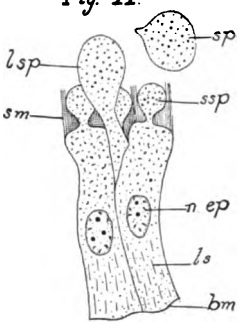


Fig. 12.

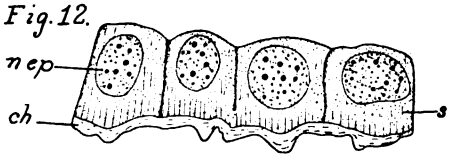
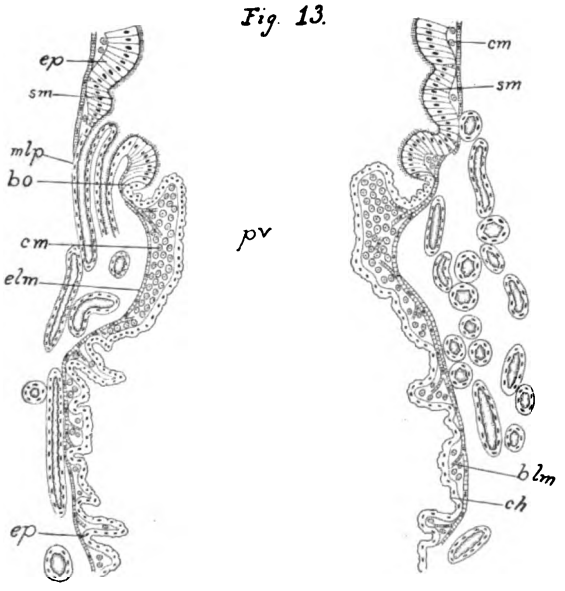
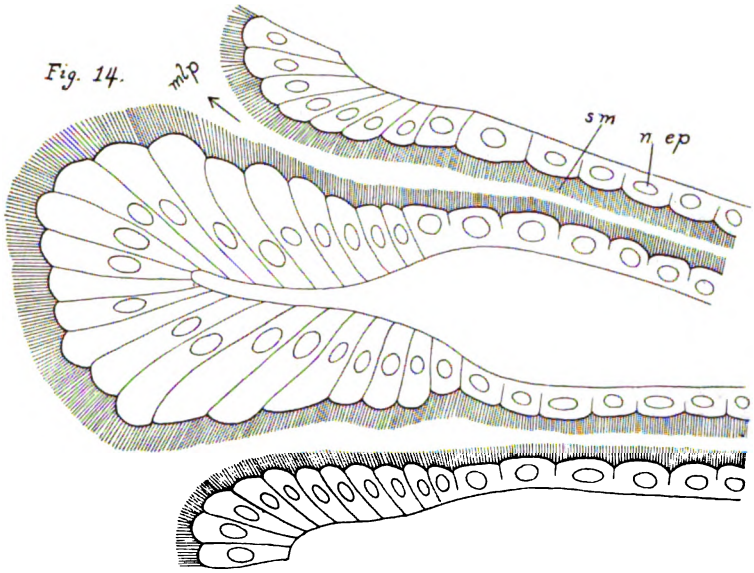


Fig. 13.





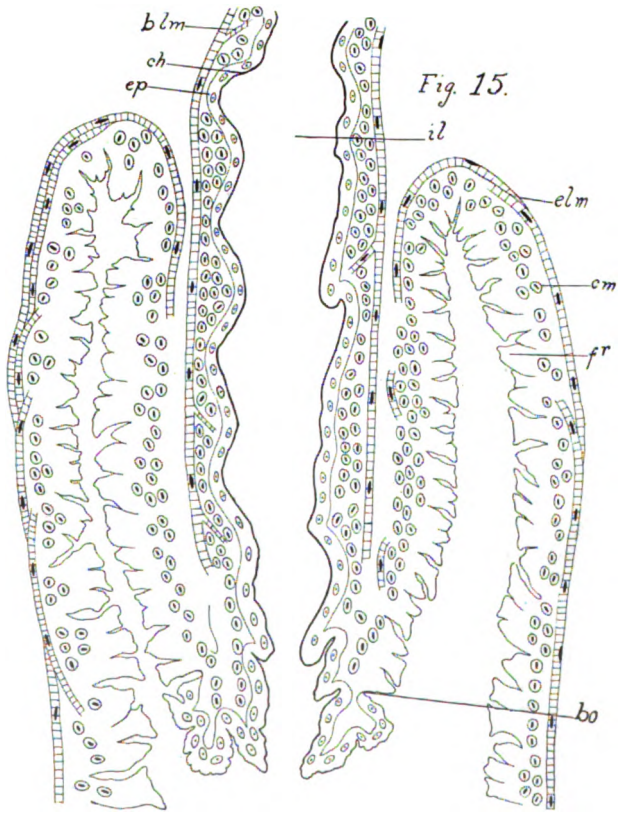


Fig. 15.

Approved Wm. S. Marshall.